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(54) Arc and induction furnace plant

(57) A furnace plant comprises at least one d.c. or a.c. arc furnace 2, 3 connected to an a.c. network 1, and a compensator 8 for compensating active power fluctuations of the furnaces 2, 3. The compensator 8 comprises at least one induction furnace for the preheating of scrap with which the arc furnaces are subsequently to be charged, the induction furnace(s) being connected to the network 1 via at least one controllable alternating voltage converter. Reactive power compensation devices 6 are also connected to the network 1.

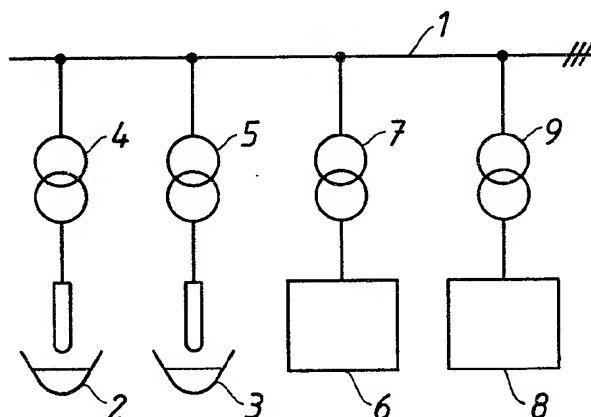
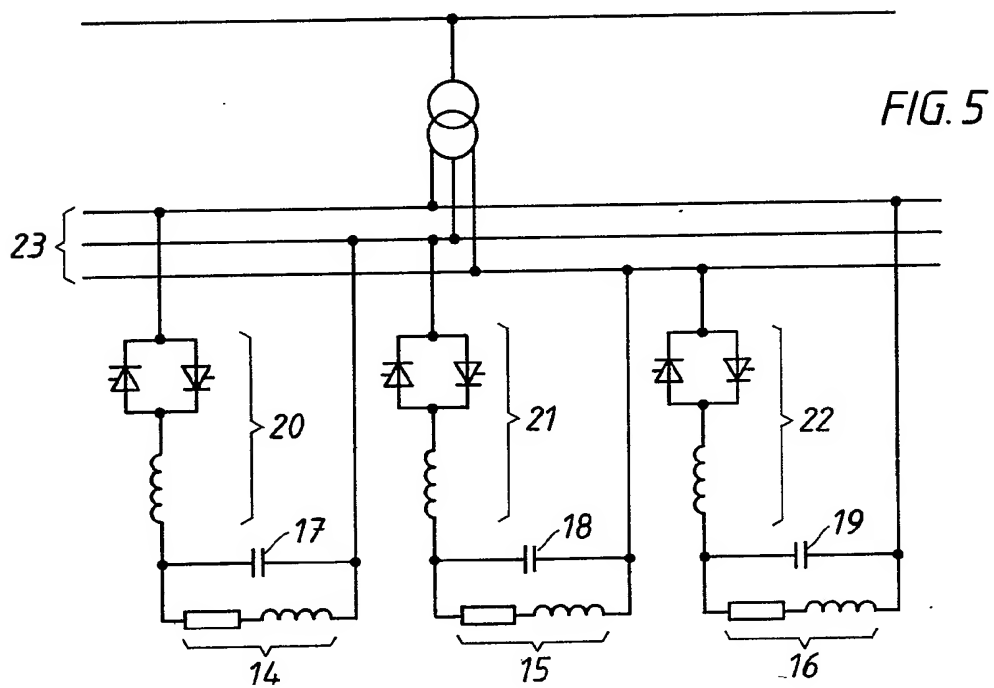
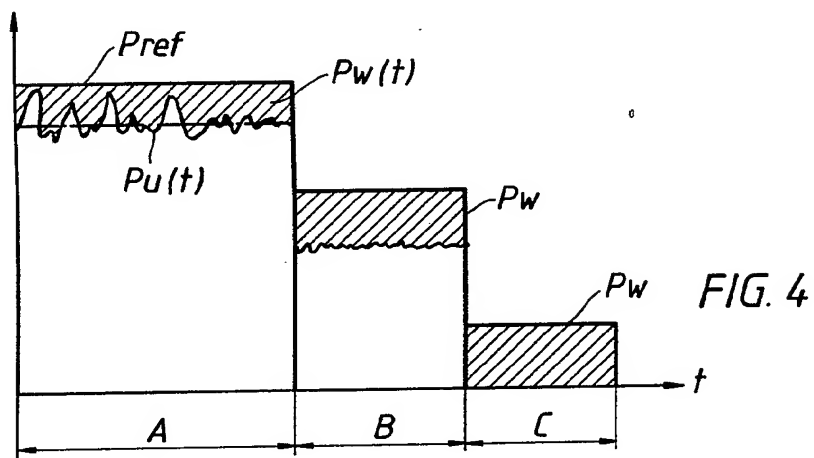
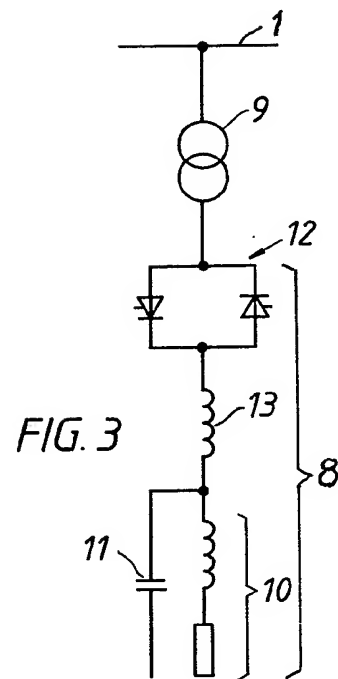
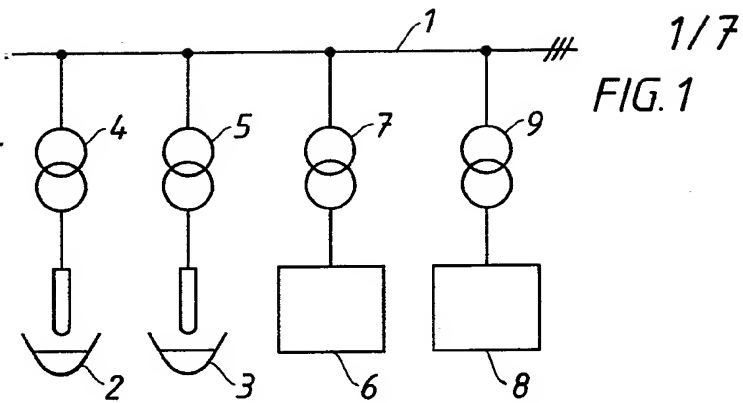
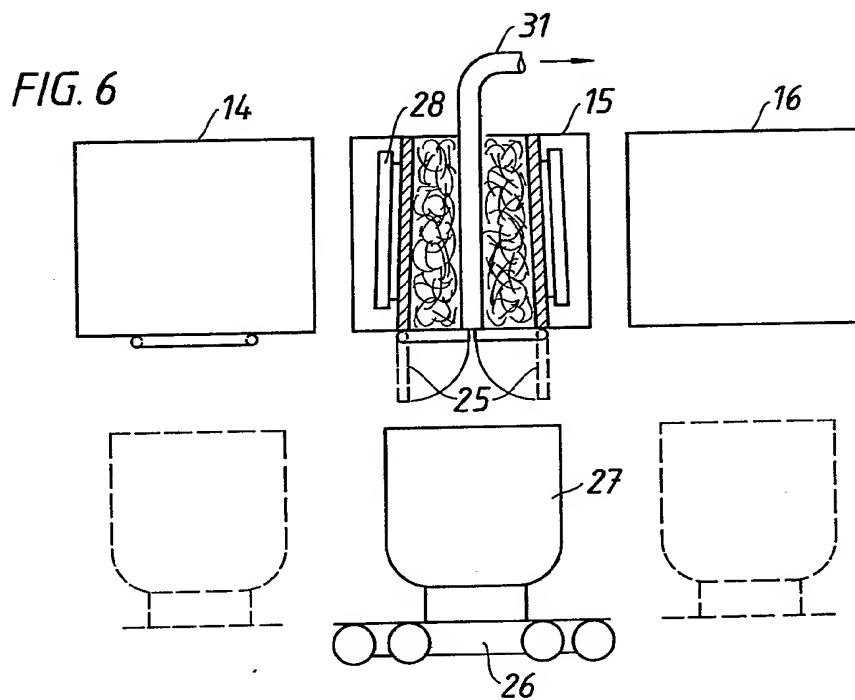
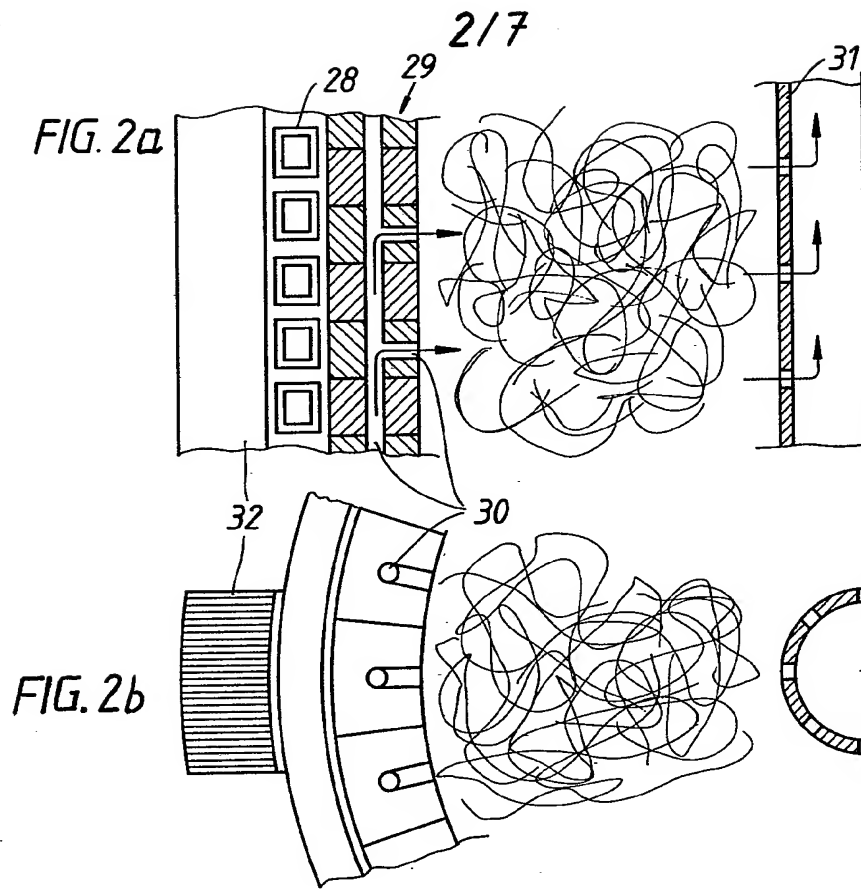


FIG. 1





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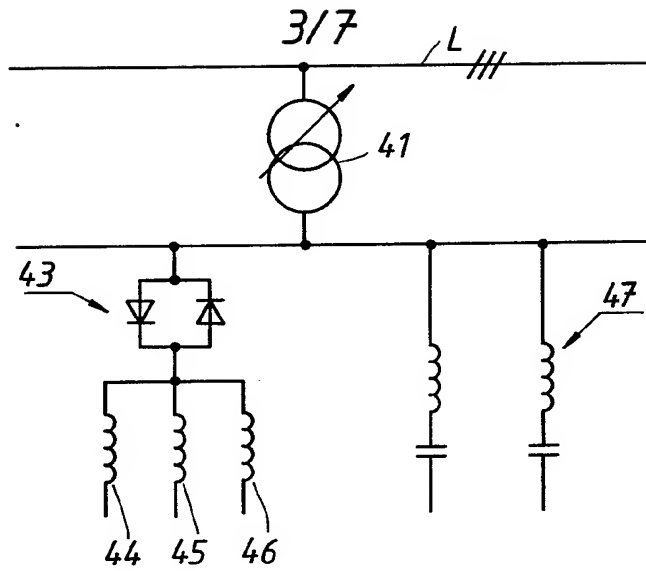


FIG. 7a

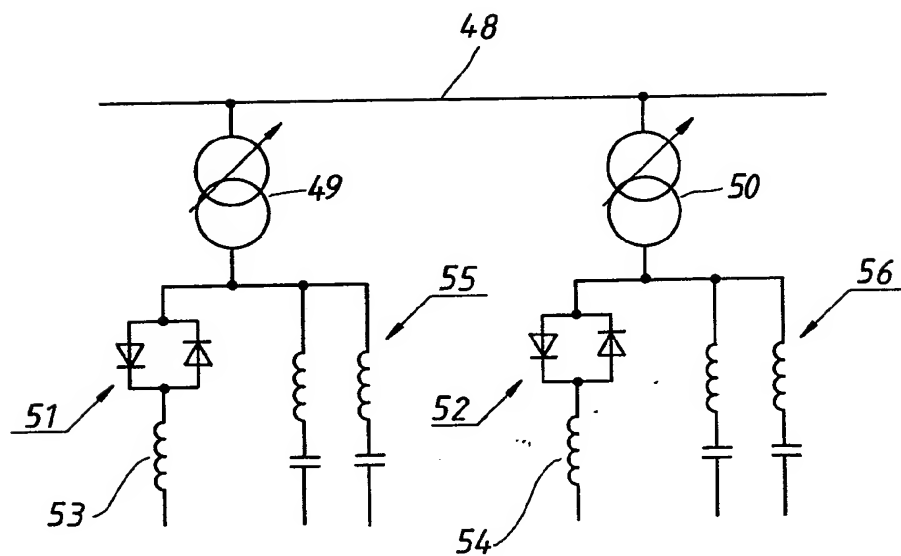


FIG. 7b

FIG. 8

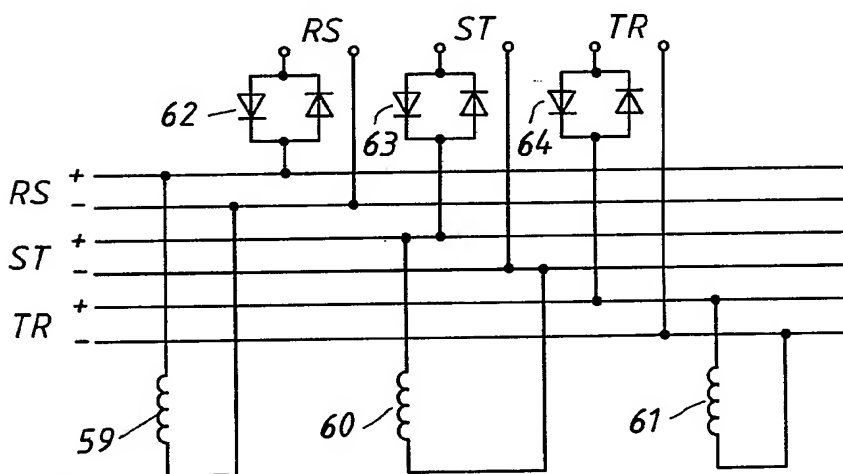
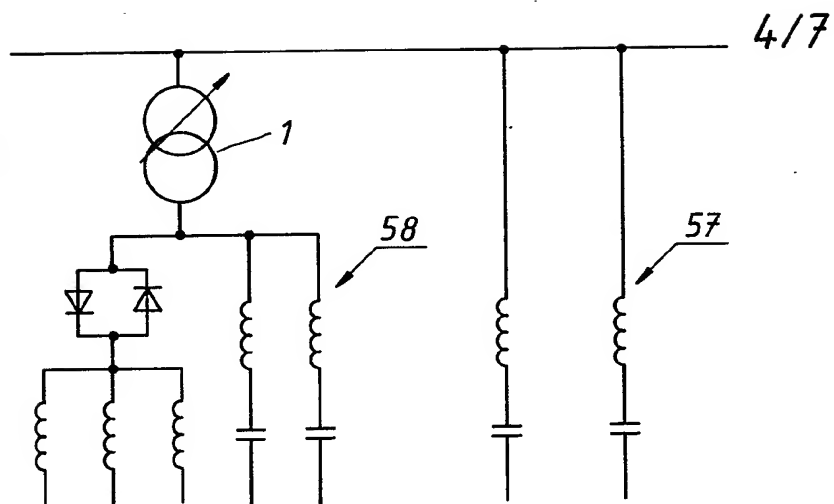


FIG. 9a

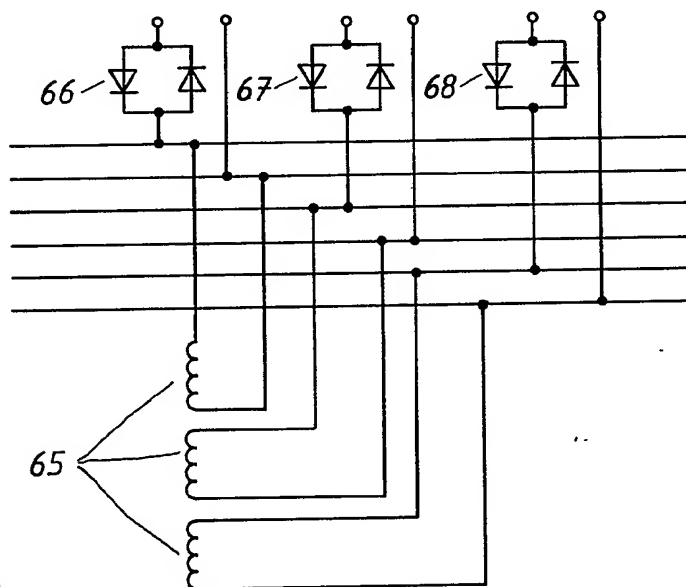
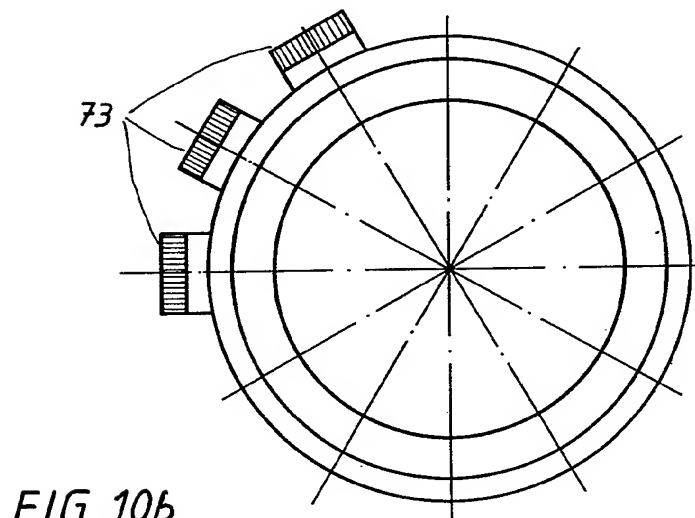
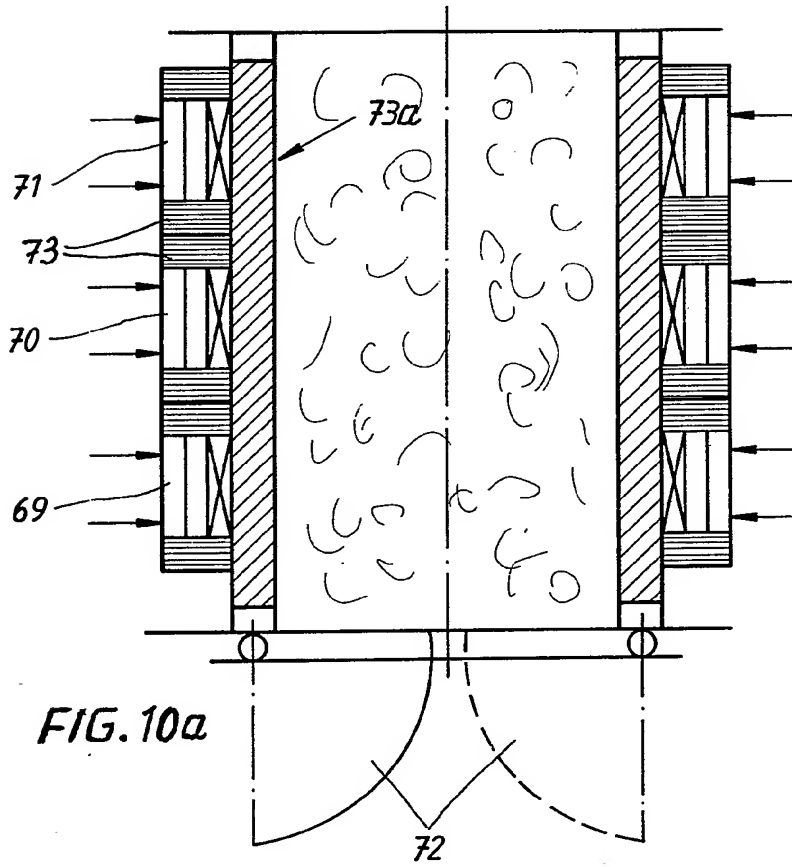


FIG. 9b

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FIG. 11

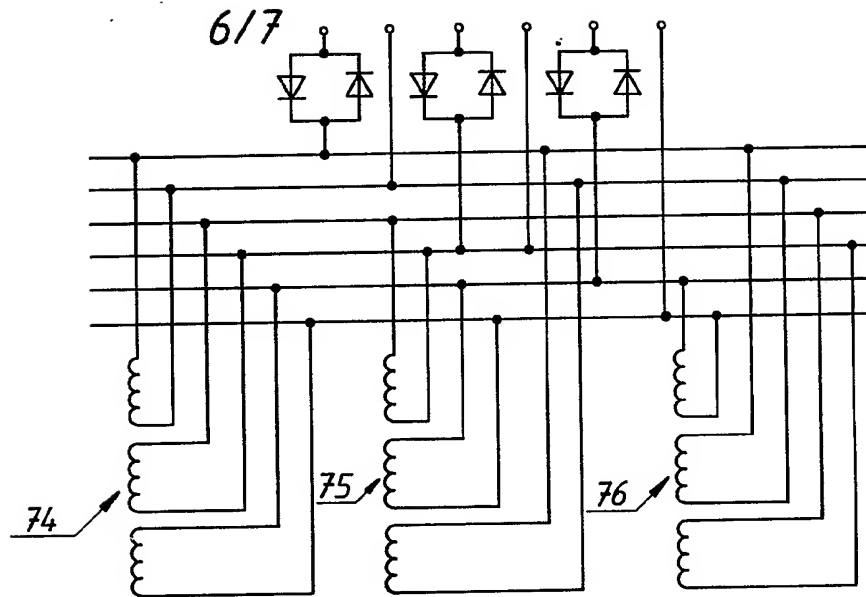
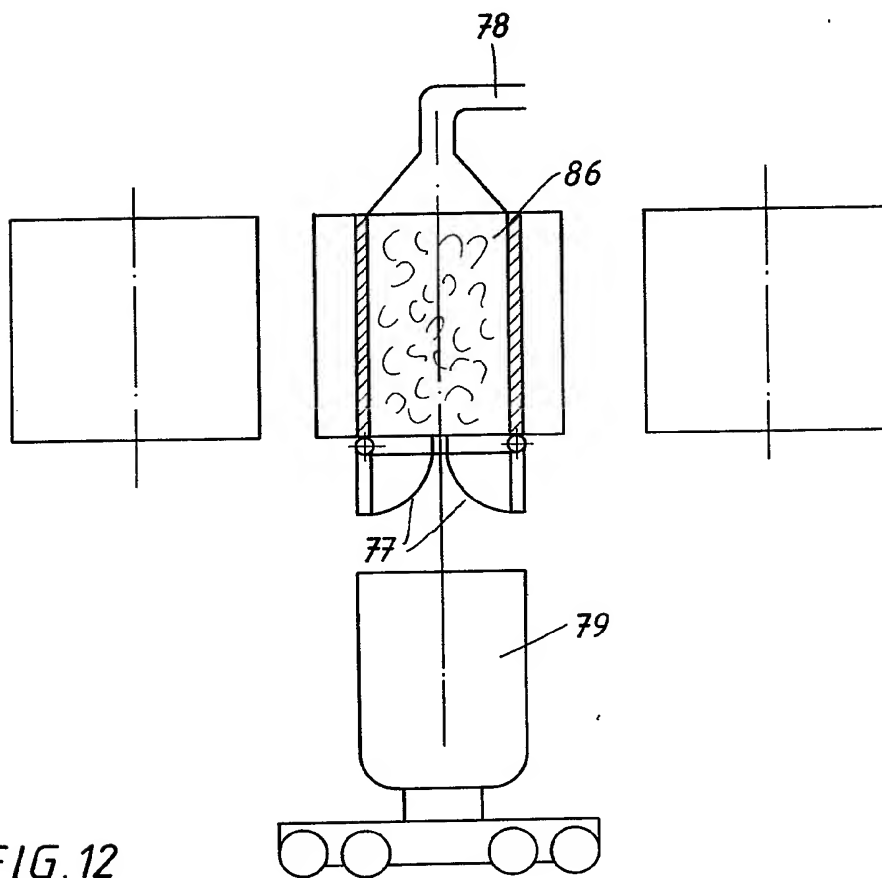


FIG. 12



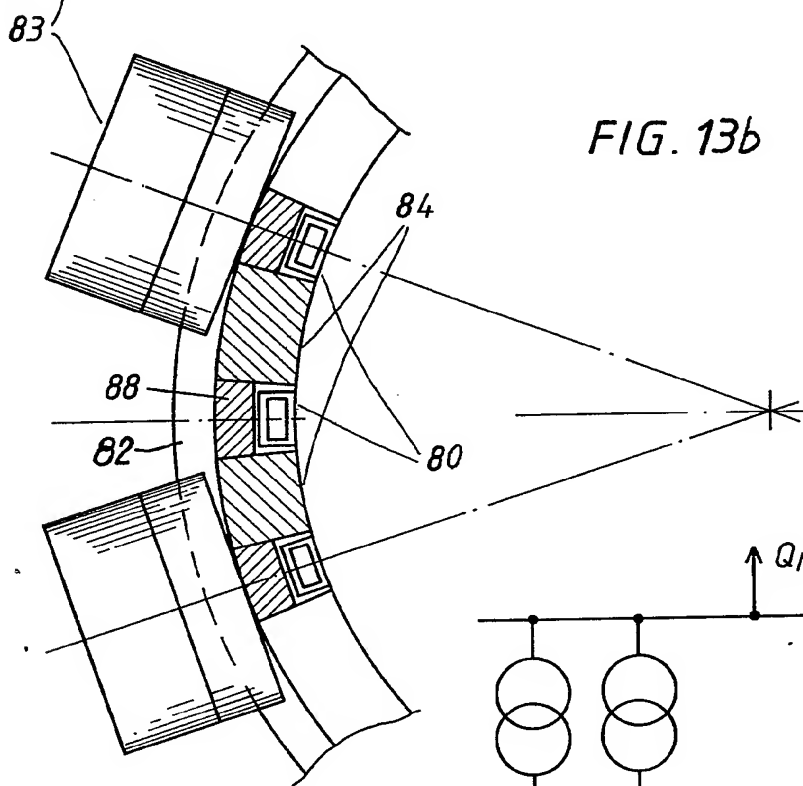
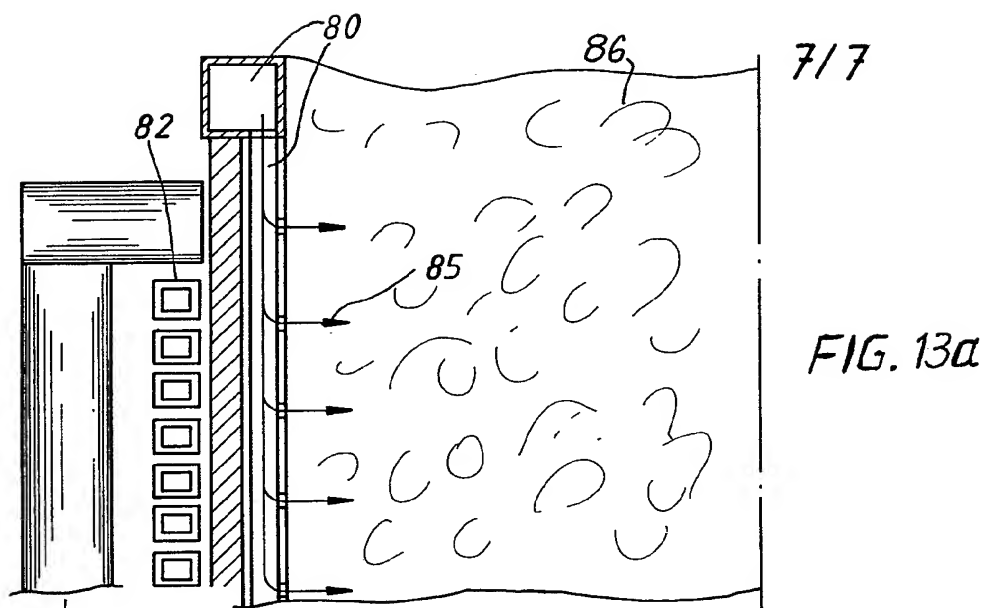
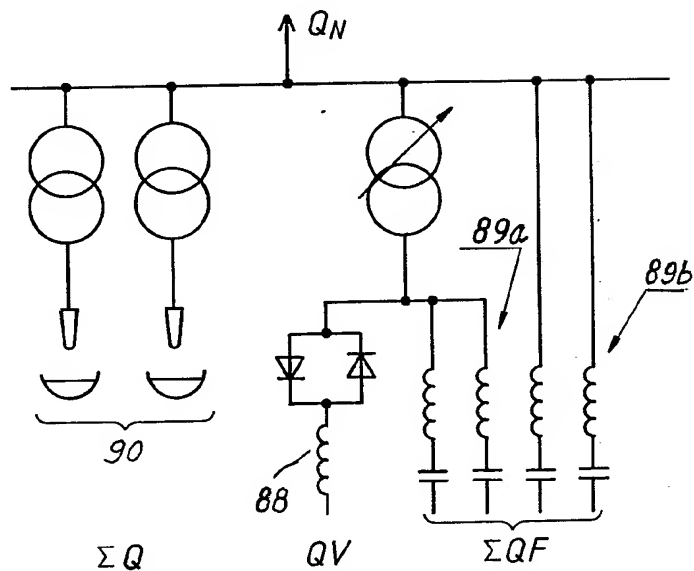


FIG. 14



## SPECIFICATION

## Arc furnace plant

5 This invention relates to a furnace plant comprising at least one arc furnace, for example three single-phase or one or more two-phase or three-phase arc furnaces, connected to an a.c. network.

Arc furnaces represent difficult load consumers for power supply systems. In particular, the reactive power fluctuations are great and cause voltage fluctuations, which may be disturbing. These reactive power fluctuations are compensated by reactive power compensating means, such as static systems comprising thyristor-connected capacitors or phase-angle controlled reactors, possibly completed by harmonic filters. However, such a compensating means cannot compensate the active power fluctuations but only have a balancing effect. In weak networks, the active power fluctuations give rise to disturbing power fluctuations despite compensation of the reactive power fluctuations. When arc furnaces are connected to weak networks in the vicinity of the power generation plant, these active power fluctuations may be detrimental to the generators as well as the turbines of the plant. The problems are great because of current asymmetries and power fluctuations.

The present invention aims to provide a furnace plant in which the above-mentioned problems are avoided.

According to the invention, a furnace plant comprising at least one a.c. or d.c. arc furnace connected to an a.c. network, is characterised in that at least one induction furnace is connected to the same network for preheating the scrap with which the arc furnace, or at least one of the arc furnaces, is subsequently to be charged. Preferably, the latter connection is made via at least one controllable alternating voltage converter.

In a furnace plant in accordance with the invention, by controlling the power supplied to the induction furnace(s), the power fluctuations of the arc furnace(s) may be rapidly and efficiently equalised so that the plant has an approximately constant power demand from the network. This solves the above-mentioned problems, and in addition a higher production and lower production costs are obtained, due, among other things, to a lower electrode consumption and shorter melt-down times in the arc furnace(s).

In the case of a furnace plant in accordance with the invention which comprises one or more d.c. arc furnaces, connection of the latter to the network is effected by way of an a.c./d.c. converter.

In a preferred embodiment of the invention, comprising a plurality of induction furnaces, each induction furnace (suitable of the crucible type) is connected to the network via a respective alternating voltage converter.

The induction furnace(s) may be arranged to compensate, at least partially the reactive power fluctuations caused by the arc furnace(s). In this case, the furnace plant comprises either a single-phase induction furnace, connected to each phase, or, in the case

of three-phase networks, one or more three-phase induction furnaces. In this case, the aforementioned phase-angle controlled reactors or the like, previously used for power factor correction, which normally consist of a number of single-phase air reactors, one for each phase, are replaced by the single-phase or three-phase induction furnaces (which may be coreless), in which the scrap for the arc furnace(s) of the plant may be heated inductively.

75 The invention will now be described, by way of example, with reference to the accompanying drawings, in which

Figure 1 is a circuit diagram of one embodiment of a furnace plant in accordance with the invention,

80 Figures 2a and 2b are a schematic sectional side view and a corresponding plan, respectively, of part of an induction furnace of a furnace plant in accordance with the invention,

Figure 3 is a circuit diagram of one embodiment of the active power compensator for the plant of Figure 1,

Figure 4 is a graph illustrating three different stages in the operation of a furnace plant in accordance with the invention,

90 Figure 5 is a circuit diagram of a second embodiment of an active power compensator of a furnace plant in accordance with the invention,

Figure 6 is a schematic side view, partly in section, of the induction furnaces of a furnace plant comprising the active power compensator of Figure 5,

Figures 7a, 7b, 8, 9a and 9b are circuit diagrams showing different arrangements of the induction furnaces of furnace plants in accordance with the invention,

100 Figures 10a and 10b are a schematic sectional side view and a corresponding plan, respectively, of another embodiment of an induction furnace for use in a furnace plant in accordance with the invention,

Figure 11 is a circuit diagram of another arrangement of the induction furnaces of a furnace plant in accordance with the invention,

Figure 12 is a view, similar to Figure 6, illustrating a modified construction for the induction furnace(s) of a furnace plant in accordance with the invention,

110 Figures 13a and 13b are a schematic sectional side view and a corresponding plan, respectively, of a further embodiment of an induction furnace for use in a furnace plant in accordance with the invention, and

115 Figure 14 is a circuit diagram of a further embodiment of a furnace plant in accordance with the invention.

Figure 1 shows a furnace plant which comprises two arc furnaces 2, 3, which are each connected to an alternating voltage network 1 via a respective transformer 4, 5. To the network 1, which is suitably a three-phase network, there is connected a reactive power compensator 6 for voltage stabilisation and compensation of the reactive powers, this compensator being connected to the network via a transformer 7. The compensator 6 consists, for example, of thyristor-connected capacitors or a phase-angle controlled reactor, possibly with harmonic filters.

A compensator 8 for the active power fluctuations is connected to the network 1 via a transformer 9.

The compensator 8 consists of an alternating voltage converter supplying an induction furnace, suitably one for each phase, or a three-phase converter supplying a three-phase induction furnace. It is also possible to have one compensator per phase and thus one induction furnace per phase, and possibly one three-phase arc furnace or three single-phase arc furnaces.

Figure 3 shows one possible form of the compensator 8, comprising an induction furnace 10 which is provided, as usual, with a parallel capacitor 11. The furnace 10 is connected to the network 1 via an alternating voltage converter, comprising two antiparallel-connected thyristors 12 and a reactor 13, the converter being connected to the network via the transformer 9.

The power fluctuations from the arc furnace(s) of the furnace plant are measured in a known manner, and the measuring signal obtained controls the thyristors 12 so that there is a relatively constant total power demand from the network.

The reactive powers of the arc furnaces 2, 3 and the active power compensator 8 are compensated for each of the phases R, S and T by the reactive power Q(VAR) absorbed in the reactive power compensator 6, which also symmetrises the active powers from the arc furnaces (Q(V)) and the induction furnace(s) (Q(W)), for example according to the following conditions:

$$\begin{aligned} Q(\text{VAR})_{RS} &= -(Q(U+W)_R + Q(U+W)_S - Q(U+W)_T) \\ Q(\text{VAR})_{ST} &= -(Q(U+W)_R + Q(U+W)_S + Q(U+W)_T) \\ Q(\text{VAR})_{TR} &= -(Q(U+W)_R - Q(U+W)_S + Q(U+W)_T) \end{aligned}$$

The compensator 8 is controlled for each of the phases R, S and T so that the active powers in the arc furnaces 2, 3 and the scrap preheating furnaces 8, 10 are constant according to the following control conditions:

$$Pu(t) + Pw(t) = Pref$$

or

$$\begin{aligned} PWRS &= 1/3 Pref - (PUR + PUS - PUT) \\ PWST &= 1/3 Pref - (-PUR + PUS + PUT) \\ PWTR &= 1/3 Pref - (PUR + PUS + PUT), \end{aligned}$$

in which  $Pu(t)$  is the arc furnace power,  $Pw(t)$  the induction furnace power and  $Pref$  the total power.

During the first stage (A in Figure 4) of the operation of the furnace plant, the meltdown stage, the power to the preheating furnace or furnaces 10 is controlled such that the peaks of the arc furnace power  $Pu(t)$  are compensated and the total power  $Pref$  becomes relatively constant. The power  $Pw(t)$  to the preheating furnace(s) is shown in the cross hatched region.

After a certain time the final treatment starts, that is, the arc power is reduced (stage B), and the peaks of  $Pu(t)$  become smaller. However, the power supplied for pre-heating of the scrap with which the arc furnace is subsequently to be charged, continues at the level  $Pw$ . During the tapping of melt from the arc furnace, (stage C), the power supplied to the latter is set to zero, and only the power  $Pw$  supplied for pre-heating is continued.

The scrap heating furnace may consist of three vertical, single-phase induction furnaces 14, 15, 16, as shown in Figure 5, with parallel capacitors 17-19 connected to the three-phase network 23 via sepa-

rate alternating voltage converters 20, 21, 22, for example of the same kind as shown in Figure 3. Alternatively, the furnaces 14-16 may be one or more three-phase induction furnaces.

As shown in Figure 6, the furnaces 14-16 may have a frusto-conical scrap-receiving chamber which is wider at its bottom than in its upper portion, in order to facilitate discharge of the scrap. The furnaces have openable bottoms 25, and are positioned in a row above a car 26 with a scrap container 27. The furnaces 14-16 are fed with scrap in a conventional manner. When charging of the arc furnace(s) with the scrap is to take place the bottoms 25 are opened in turn and the preheated scrap is received in the scrap container 27 for transportation to the arc furnace(s).

As the heating power in the preheating furnaces is developed at the periphery, the energy must be transported towards the centre. This may be achieved as shown in Figures 2a and 2b. These Figures show an induction furnace lined with perforated hard brick, in which there are provided channels 30 for air. Air is then sucked from the periphery towards the centre and is carried away from the furnace in a perforated vertical exhaust tube 31. The furnace is shown as having a furnace coil 28 and laminated cores 32. After cleaning, the heated air withdrawn through the tube 31 may be used either for local heating or as combustion air, for example for ladle preheating.

Figure 7a shows an arrangement of induction furnaces which may be used in a furnace plant in accordance with the invention. In this arrangement three induction furnaces 44, 45 and 46 are supplied by a common transformer 41 and a common alternating voltage converter 43 from a multi-phase network L. In parallel with the converter 43 and the furnaces 44-46 there are connected one or more fixedly connected harmonic filters 47, which are tuned to different frequencies to reduce the harmonics.

Figure 7b shows another possible arrangement of the induction furnaces which may be used in a furnace plant in accordance with the invention. In this arrangement, there is separate supply of different induction furnaces 53 and 54 from a multi-phase network 48. Separate transformers 49 and 50 supply alternating voltage converters 51 and 52, respectively, which in turn are connected to the furnaces 53 and 54, respectively. Harmonic filters 55 and 56 are connected in parallel with the converters 51 and 52 and the furnaces 53, 54 respectively.

To reduce the rate power of the transformer 41 in Figure 7a, fixed power factor correction may be effected in two equal halves, one half being connected to the primary side 57 of the transformer and the other to the secondary side 58 of the transformer 41, as shown in Figure 8.

According to Figure 9a, the scrap heating furnaces may either consist of three single-phase, vertical induction furnaces 59, 60 and 61, which are each provided with an openable bottom and which are each connected to a single-phase alternating voltage converter RS, ST, TR, or may consist of alternating voltage converters 62, 63, 64 via busbars RS, ST, TR (+ and -). It is also possible to connect one or more

three-phase induction furnaces with an openable bottom to the network, for example according to Figure 9b. In the latter Figure, the induction furnace is shown at 65 and the different alternating voltage converters at 66, 67 and 68. Since the compensator must be adjusted phase by phase for symmetrisation of the active powers from the arc furnaces, it is an advantage to have one or more three-phase furnaces.

To reduce the effect of the mutual inductance between the different coils, the furnaces may be constructed, as shown in Figures 10a and 10b in three different sections 69, 70 and 71, which are surrounded by iron cores 73 and stacked on top of each other. The furnace is designed with a refractory lining 73a and with an openable bottom 72.

In order further to reduce the mutual inductance between the coils in the case of two or more three-phase furnaces, the furnaces may be connected alternately to different phases, as shown in Figure 11. In this Figure, the furnaces are shown at 74, 75 and 76.

Figure 12, shows induction furnaces which are provided with an openable bottom 77 and a flue gas exhaust 78. The furnaces are arranged in a row with their openable bottoms above a car path for scrap containers 79, the latter being used in the same way as the scrap containers 27 of Figure 6.

Figures 13a and 13b show how the heating power, which is developed at the periphery of the furnace of Figure 12, is transported towards the centre. To this end, the furnace is designed with so-called guide tubes 80 of non-magnetic material, which are of rectangular cross-section and of small radial extension, and which are positioned between the iron core 83 and the furnace coil 82, on the one hand, and the scrap 86, on the other hand. Hard ceramic material, such as refractory bricks 84, is arranged between the guide tubes 80, and the latter are provided with holes, directed towards the centre of the coil 82 (see Figure 13a), through which air is blown, as indicated by the arrows 85. The air which is blown through the guide tubes 80 thus transports part of the energy from the periphery towards the centre. Above the furnace there is a hinged lid (not shown) with the flue gas exhaust 78 shown in Figure 12. The energy in the exhaust gases may be used for heating premises or for other purposes.

According to Figure 14, the reactive power compensator, the VAR compensator, is controlled with the following control conditions:

$$\Sigma Q + Q_V - \Sigma Q_F - Q_N = 0,$$

$$Q_V = \Sigma Q_F - \Sigma Q + Q_N, \quad \text{in which:}$$

$\Sigma Q$  = The reactive power in the arc furnaces 90

$\Sigma Q_F$  = The reactive power in the fixed compensation 89a, 89b

$Q_N$  = The reactive power to the network

$Q_V$  = The reactive power in the induction furnaces 88.

To balance the active power in the arc furnaces, the induction furnaces may be regulated phase by phase according to the conditions:

$$Q_{V_{RS}} = -(QR + QT - QT)$$

$$Q_{V_{ST}} = -(-QR + QS + QT)$$

$$Q_{V_{TR}} = -(QR - QS + QT)$$

where QR, QS and QT are the reactive powers at the different phases R, S and T.

Depending on the scrap composition and the temperature increase, the impedance in the furnaces will be changed from charge to charge and during each charge. The alternating voltage converters are suitably controlled by means of changes of the voltage ratio of the transformer or by means of any other type of phase angle control. Since the impedance in the furnaces is relatively constant, the active power in the induction furnaces will vary in proportion to the reactive power.

The invention is not, of course, limited to the furnace plants described in detail above with reference to the drawings. For example, the alternating voltage converter(s) of the plant may have a different number of thyristors than shown in the drawing and the thyristors may be connected in other ways than shown.

#### CLAIMS

1. A furnace plant comprising at least one a.c. or d.c. arc furnace, connected to an a.c. network, characterised in that at least one induction furnace is connected to the same network for preheating the scrap with which are arc furnace, or at least one of the arc furnaces, is subsequently to be charged.

2. A furnace plant according to claim 1, in which said at least one induction furnace is connected to the network, via at least one controllable alternating voltage converter.

3. A furnace plant according to claim 2, in which the, or each, induction furnace is connected to the network via a respective alternating voltage converter.

4. A furnace plant according to claim 3, in which each induction furnace is coreless.

5. A furnace plant according to any of claims 2 to 4, in which the, or each, alternating voltage converter comprises at least two antiparallel-connected thyristors and at least one reactor.

6. A furnace plant according to any of the preceding claims, in which the power consumed in the induction furnaces is controlled in such a way that the total active power demand of the furnace plant is maintained substantially constant, according to desired reference values.

7. A furnace plant according to any of the preceding claims, in which a reactive power compensator is connected to the network for compensation of the reactive power fluctuations.

8. A furnace plant according to any of the preceding claims, in which the, or each, induction furnace is positioned, or positionable, above a container for the reception of scrap to be forwarded to the arc furnace(s).

9. A furnace plant according to claim 8, in which the, or each, induction furnace is provided with an openable bottom.

10. A furnace plant according to claim 9, in which the, or each, induction furnace is provided with a gas exhaust tube.

11. A furnace plant according to claim 9 or 10, in which the furnace has a lining which comprises perforated bricks through which air is blown to transport heat energy from the periphery towards the

centre of the furnace.

12. A furnace plant according to claim 1, comprising either single-phase induction furnaces connected to each phase, or in the case of a three-phase network, one or more three-phase induction furnaces.

13. A furnace plant according to claim 12, in which the induction furnaces are arranged to be fed either from a common transformer and a common or separate alternating voltage converter, or from separate transformers and alternating voltage converters.

14. A furnace plant according to claim 13, in which harmonic filters are arranged in parallel with the induction furnace and the alternating voltage converter.

15. A furnace plant according to claim 12, in which the multi-phase induction furnaces are constructed in several different sections surrounded by iron cores and stacked on top of each other.

16. A furnace plant according to any of claims 12 to 15, in which the multi-phase induction furnaces are arranged so that their phase connection may be changed between the different phases or be different from furnace to furnace.

17. A furnace plant constructed and arranged substantially as herein described with reference to, and as illustrated in, Figures 1 and 3, or Figures 1 and 5, of the accompanying drawings.

18. A furnace plant as claimed in claim 12, constructed and arranged substantially as herein described with reference to, and as illustrated in Figure 7a, 7b, 8, 9a, 9b, 11 or 14 of the accompanying drawings.

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